DEVELOPING THE TECHNOLOGY MATRIX FOR INDIA AND UKRAINE

Draft Report

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EXECUTIVE SUMMARY

Introduction

Over the last decade, concern about the issues of global climate change and rising greenhouse gas emissions has grown significantly. This concern has spurred an elaborate series of international meetings and agreements seeking to stabilize atmospheric greenhouse gas concentrations. In 1992, at Rio de Janeiro, more than 160 countries, including the United States, signed the United Nations Framework Convention on Climate Change (UNFCCC). The signatories were in agreement regarding the potential negative effects of climate change under a business as usual future. Under the Convention, the developed countries (referred to as Annex I countries) were assigned primary responsibility for addressing the climate change issue. However, at the first two Conferences of Parties[1] called to discuss methods for implementing the Convention, a strong debate ensued regarding what policy instruments should be used to curb global climate change, and what, if any, targets and timetables should be set for achieving emission reductions. Most Annex I nations announced a series of voluntary targets and initiatives for meeting emission reduction goals.

By 1996, it had become clear that greenhouse gas emission levels in most Annex I countries were rising despite voluntary efforts to reduce emissions. A consensus for firmer targets and timetables was building. At the Third Conference of Parties, held in Kyoto, Japan in December 1997 a series of firm emission reduction targets were agreed to by the Parties. Developed countries agreed to reduce their greenhouse gas emissions by an average of 5.2 percent from 1990 levels by 2008-2012. While the resulting "Kyoto Protocol" was signed in 1997 by the United States and other industrialized countries, it was never ratified by the U.S. Senate, and the Administration recently announced its intention of dropping out of the negotiations surrounding the Protocol. Nonetheless, the general scientific consensus that global warming is a real, significant issue is not in dispute. The Administration is calling into question only the appropriate response to the issue, while explicitly recognizing the need for some response. Regardless of whether this response takes the form of a domestic voluntary program, an international treaty, or something in between these two extremes, it is likely that it will incorporate "market mechanisms" in some form or another. The concept of flexible, market-based mechanisms is an essential element to the Convention and the Kyoto agreement. Market mechanisms are designed to facilitate low-cost solutions to environmental problems. This new concept awards credits for emission reduction activities undertaken beyond a country's boarders.

The emission reduction activities could take the form of carbon-offset projects initiated between two developed countries or between a developed country and a developing country. Either way the host country receives the benefits of the technology transfer resulting from the project while the project developers receive any emission credits resulting from the project's emission benefits. It is important to recognize that market mechanisms are *not* designed to reduce global greenhouse gas emissions

1 The Conference of the Parties (COP) is the supreme body of the United Nations Framework Convention on Climate Change established in 1992. The body meets annually and its primary responsibility is to oversee the implementation of the Convention and the Kyoto Protocol. The Fifth Conference of Parties (COP5) is scheduled for October 25, 1999 to November 5, 1999.

beyond any potential emission reduction targets specified in an international agreement. Rather, the purpose of market mechanisms is to increase flexibility and reduce the *costs* associated with meeting emission reduction targets. As envisioned market mechanisms provide a one-to-one trade between host countries and project developers. Thus, at least in the ideal, market mechanism projects will yield no net change in global emissions. In short, it is the emission reduction targets, and not the market mechanisms that will act as the driving force for reducing global greenhouse gas emissions.

Under the Kyoto Protocol, for example, the market-based, flexible mechanism approach was manifested in the clean development mechanism (CDM). The CDM is defined as an emissions reduction project between a developed country and a developing country that provides the developing country with project financing and technology and allows the developed country to acquire emission reduction credits. The credits may be applied to the developed country's emission reduction goals. While the Kyoto Protocol, and therefore the CDM, may not come to pass, it is very likely that a mechanism similar to the proposed CDM will be incorporated into whatever climate change program, treaty, or agreement is accepted.

In order to estimate emission reductions arising from such market-based emissions reduction projects, the emissions generated by the project itself must be measured and subtracted from some baseline representing what emissions would have been in the absence of the project. The technology matrix, originally proposed by the National Energy Technology Laboratory (NETL) in the report *Developing Emission Baselines for Market-based Mechanisms: A Case Study Approach*, is a potential method for estimating the baseline. It consists of a selected list of greenhouse gas abating technologies, along with emission rate benchmarks for each technology.

In this document, a technology matrix was developed for ten selected technologies, for the countries of India and Ukraine. The basic technology matrix development approach was the same for all of the stated technologies, and for both countries. For a technology to “qualify” for the selected list of greenhouse gas abating technologies, it must first be subjected to a rigorous test to demonstrate that projects utilizing the technology are “additional” to those that would have been implemented under “business as usual” circumstances.

Once a technology has been qualified as additional, a benchmark was developed for that specific technology based on the emissions performance of a counterfactual technology(ies). The counterfactual technology represents the technology most likely to be utilized, if the corresponding advanced-technology project were to be foregone. In essence, the benchmark for a particular technology is a carbon dioxide emission rate that can be used to compute the baseline emissions for any project utilizing that technology. There are three basic steps to estimating the benchmark. First, the most likely alternative to the project must be defined in a qualitative manner. Second, the data required to quantify the benchmark must be collected for each technology/country combination. Finally, the collected data is analyzed, and used to compute the benchmark.

The technology matrix represents a cost-effective, objective, transparent, and reasonably accurate approach to quantifying project emission baselines. As a supplement to the project-specific approach, it offers significant cost advantages to projects meeting certain criteria, without eliminating from consideration projects that do not meet these criteria. In particular, it is similar to other benchmarking approaches, but with the addition of an effective, rigorous, true test for additionality.

The study documented in this report builds upon the earlier report cited above. Its purpose is to illustrate the development of the technology matrix for ten selected technologies in India and Ukraine. By undertaking the process of actually building the matrix for a few specific examples, key issues that must be addressed during matrix development are highlighted, data requirements are identified, availability of data to meet those requirements is determined, and the quality of the available data is assessed. Furthermore, through the development process, the strengths and limitations of the technology matrix approach are brought into sharper focus.

This initial attempt at matrix development is offered as a starting point for further discussion and debate on the merits and limitations of the technology matrix approach, and on ways to improve the approach. Judgments are made for illustrative purposes, and should not stand as the final basis for the technology matrix. The goal of the study is not to quantify the final, definitive benchmarks, but rather to illustrate, in a general sense, the procedures for benchmark development, to determine the extent to which the available data can support these procedures, and to identify the improvements in the existing data that would need to be made before full-scale technology matrix development could begin.

As stated, ten technologies for the countries of India and Ukraine were selected for inclusion in the initial technology matrix. The technologies selected for initial consideration include five electric power generation technologies, three transportation/transportation fuel technologies, and two other technologies. The specific technologies are as follows:

- Power generation:
  - Supercritical coal
  - Integrated Gasification Combined Cycle (IGCC)
  - Natural gas combined cycle
  - Fuel Cells
  - Wind turbines

- Transportation
  - Compressed Natural Gas (CNG) vehicles
  - Hybrid (electric-gasoline) vehicles
  - Gas-to-Liquids (new diesel)

- Other
  - Coalbed methane recovery
  - Energy-plex projects

Additionality Analysis

Under the guidelines established by the Kyoto Protocol, an eligible flexible, market-based project must result in emission reductions that are additional to any that would occur in the absence of the certified project activity (referred to as additionality) [Article 12 (5. c)]. In terms of the Kyoto Protocol, then, an additional project is defined as a project that will never be implemented unless the Protocol enters into force and the project acquires favorable financing, technology transfer, or other project-specific assistance. Again, while it is uncertain whether the Kyoto Protocol will enter into force, it is highly likely that flexible, market-based emission reduction projects will play a large role within whatever treaty, program, or agreement is ultimately accepted. Thus, the concept of "additionality" may still bear much significance.

Under NETL's proposed technology matrix, the additionality test is based on (1) an assessment of the technology's economic viability vis a vis current commercial technologies, and (2) a consideration of the market penetration achieved by the technology, throughout the world and in the country in question. If, based on these two tests, the technology is determined to be non-commercial in a particular country, it is judged additional; projects utilizing such "qualifying technologies" will automatically qualify for emission reduction credits under the technology matrix approach.

The failure of a technology to qualify as additional means only that project developers using the technology cannot rely on the technology matrix to demonstrate additionality. However, these project developers will be offered the opportunity to demonstrate the additionality of their projects using the project-specific approach. Furthermore, if the project developers can demonstrate additionality, they will still be able to use the benchmarks provided by the matrix to quantify their project baselines. This approach allows even project developers using commercial technologies to reap a substantial portion of the cost benefits provided by the technology matrix approach.

Additionality analyses of the ten selected technologies for the countries of India and Ukraine were conducted. All but one of the ten technologies qualified as additional for India and Ukraine. The sole exception, supercritical coal in Ukraine, does not qualify as additional because the technology is already an important part of the country's coal-fired power generation mix.

Development of the Qualitative Baseline

After establishing the additionality of the selected technologies, the next step in the technology matrix development process is to establish the qualitative baseline for each technology. Here, it is necessary to determine the most likely alternative to projects utilizing the technology in question. This determination defines the qualitative baseline, and provides the basis for quantifying the emission rate benchmarks to be included in the technology matrix.

The above determination was made for each of the ten technologies in India and Ukraine. Although utilizing available data and information, the qualitative baselines established through this process are inherently subjective in nature. The core hypothetical in the determination was addressed explicitly, based on informed opinion and expert judgment, for each individual technology and country. In this way, the unique characteristics of each technology/country combination were captured. Because they are based on subjective opinion, the qualitative baselines presented in this document are not offered as definitive or final, but rather as a starting point for further discussion, debate, and hopefully, the development of improved qualitative baselines rooted in a broad consensus.

The Qualitative Baseline for Power Generation Projects

In order to determine, qualitatively, the counterfactual for a qualifying power generation technology, it is first necessary to posit a project utilizing that technology. This hypothetical project should represent the "typical" application for the technology in question, because it must stand for all capacity expansion projects utilizing the technology, to be undertaken under a flexible, market-based carbon offset program. This hypothetical project is referred to as the "model project." Each qualifying technology will have its own model project, and that project will represent the typical or most common project likely to utilize the qualifying technology.

However, for benchmark purposes, the focus is not so much on the model project, but on the "model counterfactual." The model counterfactual is defined as the most likely alternative to the model project. The model counterfactual will represent the host of real world alternatives to the real world projects utilizing a particular technology. The goal is to define the model counterfactual such that it typifies these real world alternatives.

To define the model counterfactual, a number of key questions were addressed, including the following:

- Is the qualifying technology designed to meet baseload, intermediate, or peaking demand?
- What conventional technologies are being utilized to meet these load demands?
- What fuel type(s) will the qualifying technology utilize?
- Based on the above, what are the technology/fuel alternatives to the qualifying technology?

In order to provide a degree of standardization and objectivity in the counterfactual definition process, these and other key questions were incorporated in a series of “decision tables,” found in Chapter 3. Essentially, the decision table provides a means of defining, clarifying, and organizing the issues that must be addressed to define the model counterfactual. The decision table approach, however, is relatively inflexible and thus not applicable to all technologies. Wind turbines and fuel cells are difficult to address within the confines of the decision table approach; hence, these two technologies were considered separately.

A summary of qualitative baselines using the technology matrix approach is presented in Table 1. In this table, the qualitative baseline--i.e. the most likely alternative to the projects utilizing a particular technology--is defined for each technology/country combination. Technology/country combinations that were determined as non-additional are indicated by light shading. Projects utilizing these technologies may still qualify under the project-specific approach. Non-shaded technologies were determined to be additional; projects utilizing these technologies will automatically qualify for emission reduction credits under the technology matrix approach.

In a number of instances, separate qualitative baselines have been developed for different applications of the same technology. For example, two qualitative baselines are provided for wind turbine technology, depending on whether the turbines are to be used for off-grid or on-grid

Table 1. The Technology Matrix: Summary of Qualitative Baselines

Technology	Application/Gas	Country	
		India	**Ukraine**
Supercritical Coal	All	Steam turbine plant with subcritical, PCF boilers	Coal-fired steam turbine plant
IGCC	All	Steam turbine plant with PCF boilers	Coal-fired steam turbine plant
Natural Gas Combined Cycle	All	Gas-fired steam turbine plant	Gas-fired steam turbine plant
Wind Turbine	Off-grid	Diesel generators	Diesel generators
	On-grid	A composite representing average emissions rate of recently-built capacity.	A composite representing average emissions rate of all existing capacity.
Solid Oxide Fuel Cells	Commercial cogeneration	Diesel generators	Diesel generators
	Low-cost fuel	A composite representing average emissions rate of recently-built capacity.	A composite representing average emissions rate of all existing capacity.
	Distributed generation	**USE PROJECT-SPECIFIC APPROACH**	**USE PROJECT-SPECIFIC APPROACH**
CNG Vehicles	Passenger Cars	Composite of gasoline and diesel vehicles	Composite of gasoline and diesel vehicles
	Transit buses	Composite of diesel vehicles	Composite of diesel vehicles
Hybrid (gasoline/electricity) vehicles	Passenger Cars	Composite of gasoline and diesel vehicles	Composite of gasoline and diesel vehicles
	Transit buses	Composite of diesel vehicles	Composite of diesel vehicles

Technology	Application/Gas	Country	
		India	Ukraine
Gas-to-Liquids			
Coalbed Methane Recovery	Methane	**BENCHMARK NOT REQUIRED**	**BENCHMARK NOT REQUIRED**
	CO_2/Onsite electricity generation	A composite representing average emissions rate of recently-built capacity.	A composite representing average emissions rate of all existing capacity.
	Transfer of gas to pipeline	**USE PROJECT-SPECIFIC APPROACH**	**USE PROJECT-SPECIFIC APPROACH**
Energy-Plex	All	**BENCHMARK NOT PROVIDED**	**BENCHMARK NOT PROVIDED**

applications. Furthermore, in a few cases (denoted by dark shading), it was decided that a benchmark should not be developed for a particular technology/application. For example, in the case of sulfur oxide fuel cells to be used in distributed generation applications, it was decided that the project-specific approach should be employed to compute emission reductions rather than the technology matrix approach. The energy-plex concept is also excluded from the matrix because this technology has not reached a level of maturation sufficient to warrant its inclusion at this point in time. And a benchmark is not provided for estimating the methane emission reductions resulting from coalbed methane recovery projects, because a benchmark is not required: the methane reductions can be measured directly for such projects.

The Qualitative Baseline for Transportation Projects

Qualitative baselines were also developed for the three transportation technologies: gas-to-liquids (new diesel), compressed natural gas (CNG) vehicles, and hybrid (electric/gasoline) vehicles. The inherent difference in the emissions scenario of each transportation technology as they are applied to different vehicle types, such as light-, medium-, and heavy duty-vehicles, trucks, and busses, requires that a counterfactual and an emissions benchmark are quantified for each vehicle category and each transportation technology.

A determination of which specific conventional transportation technologies would have been used in the absence of the model project was made. This determination included an analysis of the types and fuel source of the counterfactual vehicles that would have been purchased. To the extent possible, the analysis targeted transportation data for the major cities of Ukraine and India, where the development of large-scale, market-based carbon offset transportation projects are most likely to occur.

The three advanced technologies included in the technology matrix were divided into two main categories. The first includes CNG and hybrid vehicles, which involves the deployment of a new type of low emission vehicles. The second category involves the introduction of a new fuel source, i.e. gas-to-liquids (diesel-based).

In the case of CNG vehicles, the most advanced vehicle applications on the market today are CNG passenger cars and transit buses. Therefore, those two CNG technologies were the focus in this study. In the hybrid vehicle category, hybrid electric/gasoline passenger cars have reached the highest stage of commercialization and should thus be considered for inclusion in the technology matrix. Other technologies, including electric/diesel, hydrogen, fuel cell, or solar powered vehicles, are being tested but are at an earlier stage of development. Of these technologies, hybrid electric/diesel transit buses were chosen as the second model project technology for hybrid vehicles. For each of the two vehicle categories, two model counterfactuals were developed -- one for passenger cars and one for transit buses.

The development of the model counterfactuals for both CNG and hybrid passenger cars and buses involved determining which type(s) of vehicles and fuel sources represent the most likely alternatives to these technologies. In India and Ukraine, each vehicle type is represented by a number of different vehicle models with different emissions qualities. The vehicles are also fueled by different energy sources, including diesel, natural gas, liquified petroleum gas (LPG) and CNG. The most likely alternatives consist of conventional transportation technologies powered by commercial fuel sources. The model counterfactuals were thus defined as a composite of all recently purchased conventional vehicles in a given vehicle category (Table 1). For passenger cars, this includes both diesel- and gasoline-powered vehicles. Vehicles powered by non-commercial fuel sources, such as LPG, were not included in the counterfactual. In the case of transit buses, the model counterfactual for CNG and electric/diesel buses was based on a composite of all new diesel-powered transit buses in India and Ukraine. Ideally, these averages or composites for the model counterfactuals should be separated into two additional categories, one for urban driving and one for country (highway) driving.

Gas-to-Liquids (GTL) technology involves the conversion of natural gas to a number of liquid synthetic fuels. GTL technology provides three potential methods for reducing greenhouse gases, including; (1) a cleaner burning diesel that will facilitate fuel replacement, (2) a means for converting natural gas that would otherwise have been flared, and (3) a low-sulfur fuel that allows for the development of advanced, fuel-efficient compression-ignition diesel engines. However, at this time, none of these potential emission reduction methods will require the development of an emissions benchmark for inclusion in the technology matrix. Fuel replacement projects are not likely to qualify as additional under a flexible, market-based carbon offset program because traditionally such projects are developed in response to local air quality regulations. Flared natural gas projects do not require the development of an emissions benchmark because the metered amount of gas recovered will provide an estimate of the greenhouse gas reductions. Finally, advanced clean-burning diesel-engines have not yet reached beyond the early development stage, making it unnecessary to develop an emissions benchmark at the present time.

The Qualitative Baseline for Coalbed Methane Recovery

In some countries, such as India, interest in coalbed methane recovery is growing because it is seen as a means of recovering a potentially valuable, indigenous source of energy. Given India's interest in coalbed methane as a potentially large, valuable resource, and the current circumstances surrounding the country's mining industry, it is quite possible that, in India, coalbed methane recovery efforts may proceed independently of mining. It was thus necessary to consider both possible types of coalbed methane recovery projects: those carried out independently as well as those undertaken as a concomitant to mining.

It was concluded that a benchmark (and a model counterfactual) is not required to estimate the methane emission reductions resulting from these projects. If a particular coalbed methane recovery project is undertaken in association with a mining operation, the resulting methane emission reductions can be estimated on the basis of measurements of the quantity of methane recovered. If a project is undertaken independently of mining, it will not reduce methane emissions (unless and until the seam is mined).

The model counterfactual for estimating the carbon dioxide emission reductions resulting from a coalbed methane recovery project depends on the uses to which the methane is put:

- If the recovered gas is used to generate electricity on-site, either for on-site use or for sale to the grid, the composite approach used to define the model counterfactual and benchmark for other small-scale power generation projects (e.g., wind turbine projects) should be applied. Specifically, for India the counterfactual should represent a composite of all recently-built capacity, with a benchmark equal to the average heat rate for this new capacity. For Ukraine, the model counterfactual should be a composite of all existing capacity, with a benchmark equal to the average emissions rate for the Ukrainian electricity sector.

- A benchmark cannot be supplied for coalbed methane recovery projects involving the transfer of the recovered gas to a natural gas pipeline, due to the high degree of uncertainty surrounding the nature of the model counterfactual, and the ultimate uses of the recovered gas, for such projects. However, project developers may use the project-specific approach to demonstrate their claim to carbon dioxide emissions resulting from such projects.

The Qualitative Baseline for Energy-Plex Projects

The concept of the energy-plex forms the core of "Vision 21," NETL's program for developing clean energy plants for the twenty-first century. Essentially, an energy-plex is conceived of as an advanced, ultra-high efficiency, fully-integrated energy production facility capable of producing multiple energy products (e.g., electricity, steam, liquid transportation fuels, chemicals, hydrogen, etc.) from a variety of fuel inputs. Energy-plex plants would be designed to maximize efficiency, by maximizing the utilization of the various fuel inputs. The ultimate goal would be to use as much of the energy in the fuels as possible. The energy-plex would utilize advanced technologies such as IGCC, fuel cell/turbine hybrids, and indirect liquefaction. These technologies would be developed as modular components, which could be combined in a variety of ways to meet site-specific market requirements.

Rather than attempting the full-scale development of quantitative benchmarks for energy-plex projects, it became necessary to consider, in broad outline, a potential benchmark development approach geared to this highly complex set of technologies. The energy-plex concept is a very advanced idea that remains at this point in the initial "drawingboard" stage. Because any benchmark developed at this point would prove obsolete by the time it is used, benchmark development for the energy-plex concept should be postponed until that concept has reached a more mature stage of development.

However, future development of benchmarks for energy-plex projects must differ from that used for the other technologies covered in this document, as the energy-plex concept represents an integrated system of advanced technologies. The project-specific approach is a very reasonable option for the energy-plex concept, and should be given careful consideration as the concept matures and moves closer to deployment. However, the technology matrix approach may also be worthy of consideration, if it can be tailored to provide a set of benchmarks for each of the modules comprising the energy-plex, rather than a single benchmark.

Data Analysis and Benchmark Development

Following the definition of the model counterfactuals, these counterfactuals were quantified by estimating the emission rate (or heat rate) benchmarks for each technology/country combination. The benchmarks were developed based on an analysis of data collected for the electricity and transportation sectors in India and Ukraine. Subsets of the databases that meet the criteria necessary for benchmark development were identified and selected for further analysis. In some cases, data were rejected because they were determined to be outliers, or because they appeared to be suspect in some way. The remaining data were used to compute the benchmarks. In general, the benchmark was computed as the average emission rate (or heat rate) for the facilities or vehicles included in the final data subset.

Benchmarks have not been computed for many of the technology/country combinations, because the data required to compute the benchmarks were not available in time for this draft report. Data collection is proceeding in both Ukraine and India, and new benchmarks will be added to Table 15 of Chapter 4 in later versions of this report. Benchmarks were, however, developed for two of the electricity generation technologies in India, as described below.

Electricity Generation Technologies in India

Two separate databases were obtained on Indian power plants. The first of these was the Utility Data Institute (UDI) database, which includes both operating and planned units. For each generating unit, the UDI database provides data on a variety of items, including: utility, power plant, and unit name or identifier; unit location (city and State); operating status; prime mover; nameplate capacity; year of commissioning; primary fuel type; and, alternate fuel type. Shortcomings of the database include: lack of data on power plant efficiency or heat rates; and lack of data on the two items that could be used to compute heat rates--fuel consumption and net generation. Since estimation of the benchmarks requires heat rate data, the UDI database was not sufficient in and of itself for our purposes.

The second database was originally developed in support of a U.S. Environmental Protection Agency (EPA) study of the benchmarking approach to flexible, market-based carbon offset project analysis. This "EPA database" does not cover the entire population of generating units. Furthermore, the database provides data at the power plant level, and it is limited to coal-fired plants. The informal data gathering technique utilized for this database falls short of a statistical sampling approach. Nonetheless, the EPA database provides excellent coverage of India's coal-fired power plants. Furthermore, the EPA database provides a time series of fuel consumption and net generation data for each generating unit. Specific items provided by the EPA database include: power plant name; number of generating units and unit capacities; location (State); prime mover; year of commissioning; average calorific value of the coal consumed; coal consumption; and net generation. The coal consumption and net generation data are provided on an annual basis for the period 1990-99. Use of this database allowed for computation of annual heat rates for each power plant. However, one serious drawback of the database is that it provides only a single calorific value for the coal used by each power plant.

Two of the power generation technologies (i.e., supercritical steam and IGCC) require benchmarks representing the average or typical heat rates for newly-built, subcritical steam turbine units utilizing pulverized coal as the primary fuel. While the EPA database provides the necessary data to support benchmark development for these two technologies, it will not support the development of benchmarks for the three remaining power generation technologies. Since the EPA database covers only coal-fired plants, and the model counterfactual for natural gas combined cycle technology was defined as a gas-fired steam turbine plant, a benchmark for this counterfactual could not be developed. Because the limitations of the EPA database do not allow the development of alternatives to coal-fired benchmarks, the focus was limited to the development of the standard country-wide benchmarks for supercritical steam and IGCC. In defining the group of power plants that will form the basis for the benchmarks (i.e., the "benchmark group") for both of these technologies, this study was limited to recently built plants—specifically, plants opened in the last five years.

Five power plants formed the final benchmark group for supercritical and IGCC technology in India. With one exception, these plants comprise two generating units; there are a total of 11 units. Furthermore, most of the units (6) are 210 MWs in size, suggesting that they may to at least some degree utilize a standardized design. The total capacity of the five plants is 2970 MWs. This represents 3.0 percent of India's total coal-fired capacity, and 24.4 percent of coal-fired capacity opened since 1995—a good-sized sample.

Because the EPA database does not provide the data necessary to compute accurate annual heat rates, for benchmark development purposes, the study was limited to the computation of an average life-of-plant heat rate (possibly excluding the first year of operation) for each plant. The benchmark for supercritical coal and IGCC technology was found to be 10,211 Btus/kWh (10.211 MMBtus/MWh), the average life-of-plant heat rate for the five benchmark power plants. A heat rate value, rather than an emissions rate value, is used as the benchmark to enable a more accurate computation of baseline emissions using coal-rank specific emission factors.

Updating the Benchmarks. It will be necessary to select a new benchmark group of power plants on a periodic basis, to reflect changes or improvements in the operating efficiencies of new coal-fired power plants. It is believed that re-estimation once every 5 years will be sufficient to keep the benchmark up to date, since the average heat rate of new conventional steam turbine plants tends to be fairly stable over time.

The benchmark group of power plants provides a means of benchmarking projects, not just at project initiation, but throughout the projects' lives. By continually updating the data on the average heat rate for the five Indian power plants selected as the benchmark group, systemic changes in heat rates over time can be captured. The benchmark group provides a means of quantifying what would have happened in the absence of the project, not just at project initiation but throughout the project's life.

Data Quality Assessment. It is clear that the EPA database, used as the basis for the benchmark, is problematic and suspect in a number of respects. This reality resulted in the elimination of two of the seven potential candidates for inclusion in the benchmark group, thereby significantly reducing the size and scope of the sample. The benchmark estimate of 10.211 MMBtus/kWh may suffice for the purpose of this report─i.e., to explain the technology matrix concept and to illustrate, in broad outline, the procedure for developing the matrix. However, given both the known and potential unknown data problems, this benchmark does not likely meet the criteria for application to actual flexible, market-based carbon offset projects. The data upon which it is based must first be improved.

Beyond the immediate data problems, it is clear that what is really required of India is not simply a better database, but the institutional capacity needed to support the data requirements expected to be necessary for the successful implementation of an international carbon offset program. Informally obtained, un-verified, ad hoc databases cannot serve the long-term requirements of benchmarking. For one, the data collection effort must be extended to include all of India's power plants, or at least a statistically representative sample of plants. Further, the needed data must be collected on a regular, periodic basis to support the benchmark updating process. Most importantly, the data must be subjected to validation and verification procedures, to ensure a reasonable degree of accuracy. To support benchmark development for the Indian power sector, some sort of data collection agency will need to be established. To build this institutional capacity, India and other developing countries planning to participate in an international carbon offset program may require both financial and technical assistance from developed countries.

Conclusion and Recommendations for Further Work

Summary

This report illustrates the development of the technology matrix for ten selected technologies in India and Ukraine. For each technology/country combination, additionality (or non-additionality) was established. Then, the model counterfactual—the most likely alternative to projects utilizing the technology—was defined. Data of the type required to estimate emission rates were collected for the two countries. The available databases were analyzed, and subsets of the data that could be used to represent the model counterfactuals were selected. These data subsets were checked for outliers and suspect data. Finally, the "cleaned" data subsets were used to compute emission rate (or heat rate) benchmarks for each technology and country.

The results of this process are shown in Table 2. This table *is* the technology matrix for the ten selected technologies in India and Ukraine. The table indicates which particular technology/country combinations qualify as additional, and which are non-additional. It also provides an emissions benchmark for each combination.

The technology matrix is designed to significantly reduce the costs associated with the evaluation of flexible, market-based carbon offset projects. It is therefore very simple to use. Project developers would first determine whether or not their projects meet the criteria that would allow them to use the technology matrix. Essentially, projects involving the development of *new* capacity, to meet *new* demand, qualify for use of the technology matrix. On the other hand, the project-specific approach should be used to estimate the baseline for projects involving modifications to existing facilities or vehicles. If a particular project meets the criteria, the developers would then refer to Table 2 to determine whether or not the project utilizes qualifying technology. If the project technology does not qualify as additional in Table 2, the developers still have the opportunity to demonstrate the project's additionality using the project-specific approach. If the project does utilize technology identified as qualifying in Table 2, it would presumably automatically qualify for emission reduction credits under a flexible, market-based, international carbon offset program.

Once a project has been demonstrated to be additional, using either the technology matrix or the project-specific approach, the appropriate benchmark from the technology matrix can be used to estimate the project's emission baseline for each year the project is in operation. The project's actual emission reductions are subtracted from the emissions baseline to yield the estimated emission reductions in any given year. The developers would receive emission reduction credits equal to the estimated emission reductions.

The technology matrix approach offers a number of potential advantages. It is designed to substantially reduce the costs of project evaluation to project developers. It is similar to benchmarking, but with the addition of a stringent, true test for additionality based on economic and market evaluations of project technologies. Furthermore, the focus on individual technologies rather than sectors or sub-sectors enables the tailoring of benchmarks to groups of projects characterized

Table 2. The Technology Matrix for Ten Selected Technologies in India and Ukraine

Technology	Application/Gas	Country	
		India	Ukraine
Supercritical Coal	All	10.211 MMBtus/MWh	DNA
IGCC	All	10.211 MMBtus/MWh	DNA
Natural Gas Combined Cycle	All	DNA	DNA
Wind Turbine	Off-grid	DNA	DNA
	On-grid	DNA	DNA
Solid Oxide Fuel Cells	Commercial cogeneration	DNA	DNA
	Low-cost fuel	DNA	DNA
	Distributed generation	**UPS**	**UPS**
CNG Vehicles	Passenger Cars	DNA	DNA
	Transit buses	DNA	DNA
Hybrid (gasoline/electricity) vehicles	Passenger Cars	DNA	DNA
	Transit buses	DNA	DNA
Gas-to-Liquids			
Coalbed Methane Recovery	Methane	**BNR**	**BNR**
	CO_2/Onsite electricity generation	DNA	DNA
	Transfer of gas to pipeline	**UPS**	**UPS**
Energy-Plex	All	**BNP**	**BNP**

DNA: Data Not Available; may become available for subsequent version of this draft report.
UPS: Benchmark Not Provided, use Project-Specific Approach
BNR: Benchmark Not Required
BNP: Benchmark Not Provided

by similar technological characteristics. The resulting benchmarks exhibit a high degree of specificity with respect to both the technological and market characteristics of individual projects.

The technology matrix approach is designed as a supplement to, rather than a substitute for, the project-specific approach. Projects that do not meet the criteria for technology matrix utilization--mainly projects involving modifications to existing facilities or vehicles—would be required to use the project-specific approach. Because the project-specific approach remains the default, the technology matrix approach would presumably not in and of itself eliminate any projects from participation in an international carbon offset program; project developers always have the opportunity to use the project-specific approach if they cannot use the technology matrix.

Again, the technology matrix developed in this report, and presented in Table 2, is for illustrative purposes only. It is not intended to represent the final, definitive technology matrix for the ten selected technologies in India and Ukraine. Rather, the goal has been to highlight the main issues associated with matrix development, and to bring the strengths and limitations of the technology matrix approach into sharper focus, through the development of a concrete, illustrative example.

Recommended Technology Matrix Development Improvements

Through this approach, we have been able to identify two key areas where further improvements in the technology matrix development process are needed. First, the process of defining the model counterfactual is highly subjective, relying as it does on expert opinion and judgment. Given the subjective nature of the model counterfactuals, it is important that they be selected based on a broad consensus rather than the opinions of a few individuals. Thus, we would recommend the use of a Delphi approach to define the model counterfactuals for any future versions of the technology matrix.

Second, the data available to support baseline development is not adequate to the task, at least in the case of India. We wish to emphasize that, in our belief, this conclusion holds not only for the technology matrix approach, but also for *all other* baseline development approaches that have been discussed in the literature. Although the specific data requirements will vary somewhat from one approach to another, we believe that all of the various approaches will have some basic requirements in common.

All baseline development approaches will require data on a *continuing* basis, so that the emission baselines can be updated periodically. India does not at present possess the institutional capacity required to provide the needed data updates. To meet the expected data needs of a flexible, international carbon offset program, either the existing data collection agency must be upgraded, or a new agency must be established to collect and validate the needed data. To build this institutional capacity, India and other developing countries planning to participate in such a program may require both financial and technical assistance from developed countries.

Recommendations for Further Work

Rather than further development of the technology matrix at this point in time, we recommend a shift in focus to the *marketing* of the technology matrix concept. As yet, this concept is not well known beyond NETL. The marketing effort could begin with the wider dissemination of the report *Developing Emission Baselines for Market-based Mechanisms: A Case Study Approach*. This report lays the groundwork for the technology matrix approach, and is in many ways a prerequisite to the present report. Dissemination of the earlier report should be followed up with the finalization and dissemination of this present report. The preparation of one or more papers summarizing the key findings in the earlier and the present report would be a logical next step. Conferences, where these papers could be presented, should be identified. In addition, one or more articles summarizing the reports might be prepared for publication in appropriate journals. NETL attendance at flexible, market-based program-related conferences and workshops should perhaps be stepped up, and full advantage should be taken of any opportunities to disseminate the reports, papers, and articles at such events. Finally, some consideration might be given to the possibility of an NETL-sponsored workshop, to explore various approaches to flexible, market-based carbon offset project evaluation, including the technology matrix.